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ABSTRACT

This study used Bloom's Taxonomy in conjunction with new and emerging research paradigms, such as discourse analysis, to examine the outcomes of online science instruction in various biomedical science courses (i.e., histology, histopathology, physiology, microbiology, and farm animal anatomy). By combining quantitative and qualitative data, a fuller picture of how distance delivery affects student learning in the context of various science courses is developed. Data sources included chat transcripts, course exams, direct observations, and student surveys. Results show that it is possible to teach a science course, including laboratories, entirely online without any adverse effects on academic outcomes. By addressing the effects of a delivery system on classroom interactions and academic performance for science content, the study makes a contribution to the body of knowledge about distance education. (Contains 24 references.) (MES)

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Teaching Science Online – Hands Off is Not Minds Off!

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Theoretical Framework:

The total number of college courses being offered at a distance is growing exponentially, and an estimated 2.2 million students are expected to be enrolled in distance-delivered courses by 2002 (IDC, 2000). In 1999, 46.5% of Universities offered one or more full college courses online (Green, 1999). While development of online courses for liberal arts, business and technical pursuits is advancing at a rapid rate, very few science courses are offered online, and we know little about the effects of this type of delivery on student learning. A study conducted by the National Center for Education Statistics (NCES) in 1999 revealed that of the 49,690 credit-granting distance education courses offered nationwide during the 1997-98 school year, less than 5% (2,160) were in the physical and biological sciences, and only 1.5% (620) were in the areas of agriculture and natural sciences. Leading funding agencies, such as the National Science Foundation (NSF, 2001) and the Fund for the Improvement of Postsecondary Education (FIPSE, 2000), have not yet funded projects involving the development or assessment of online laboratories in the life sciences.

A soon as a teaching technique is proposed for distance education, the issue of whether it is the methods or the media that will lead to learning is inevitably raised. Whether or not electronic media can influence learning has long been debated in the literature. Clark (1983, 1994a, 1994b) states "media are mere vehicles that deliver instruction but do not influence student achievement..." (1983, p. 445), while Kozma (1991, 1994a, 1994b) feels "both media and methods influence learning and they frequently do it by influencing each other" (1994b,p. 11). It can be concluded that the media itself does not cause differences in learning but does facilitate teaching methods that may affect learning. This paper will take a different view on the issue and present the position that designers should not focus on answering the media vs. methods question, but should instead work towards selecting the most appropriate combination of media AND methods for the delivery of online science courses.

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Research about the effects of online delivery in the sciences has been conducted by Urven et. al. (2001), but this study utilized a hybrid (face-to-face and distance) delivery approach. Offering upper-level undergraduate science courses with laboratories online is a particularly noteworthy innovation, as the difficulties associated with teaching science over the Internet have been well documented (Warner & Wilkinson, 1992; Carr, 2000; O'Bannon et. al., 2000; Aviv & Golan, 1998; Palmquist, 2000). These problems include issues related to faculty-student communication, content rigor, thinking skills and laboratory instruction. For example, the lack of hands-on laboratory sessions has been cited as a potential deficit for learners (Carr, 2000). To date, institutions such as Athabasca University have dealt with this problem by requiring students to attend intensive, on-campus laboratory sessions, usually over a weekend (Kennepohl & Last, 1997).

The development of higher-order thinking skills is crucial to the preparation of competent scientists. While several methods have been developed for scaffolding this type of cognitive development in traditional situations (i.e. "discovery-based" laboratories), comparable methods must be developed and validated for online instruction if distance delivery is to be a viable means of instructing students. There is a need to develop interactive, open-ended laboratories to facilitate true experimentation in online courses. Discovery, inquiry and investigation are at the heart of science learning, regardless of how instruction is delivered. According to Jarrett (1997), "Inquiry is the set of behaviors involved in the struggle of human beings for reasonable explanations of phenomena about which they are curious" (p. 2). Inquiry is of particular importance in the sciences because it is "a way of developing the mental processes of curiosity and investigation so that students learn how information is obtained" (Trowbridge & Bybee, 1990, p. 208). Though some research has been conducted on distance-delivered laboratories (Boone, 1996), it focused on hybrid-delivered courses, resulting in a 'missing link' in available information regarding assessment of learning in these environments. Providing this information will contribute to filling this void and will allow educators nationally to analyze the impact of online laboratory teaching.

This project uses a previously established and validated measurement scale (Bloom's Taxonomy; Bloom & Krathwohl, 1956) in conjunction with new and emerging research paradigms, such as discourse analysis, to examine the outcomes of online science instruction in various biomedical science courses. By combining quantitative and qualitative data, we develop

a fuller picture of how distance delivery affects student learning in the context of various science courses.

Methods:

a) Histology:

The Histology course materials were examined using a combination of qualitative and quantitative methods to evaluate the effects of distance delivery on student learning (Schoenfeld-Tacher, McConnell & Graham, 2001). Observations were conducted in two sections (on-line and f2f) of the same course, taught by the same instructor over the course of one semester. Students in both sections completed the same pre-test, and the instructor presented the same lectures, using the same clinical examples in both situations. Learning outcomes were assessed by student achievement on course exams. The same exam questions were asked of students in both sections, but at different times during the semester. Student scores were compared in order to determine if there were any differences in performance between students enrolled in each of the sections.

Classroom interactions were observed in three settings: f2f lecture, on-line class (instructor present) and on-line review (instructor absent, student-organized study sessions). Transcripts of interactions in each setting were independently coded and analyzed by both of the researchers. An interaction was defined as any utterance from a participant in the form of a question. Each question was coded into one of four topic categories: administrative, content, management or social. Content questions were further classified according to the demonstrated level of abstraction or depth of thought, in accordance with the definitions established in Bloom's Taxonomy.

b) Histopathology:

The Histopathology course is being developed as a series of 10 modules representing each of the major body systems. Online lessons are presented so that students can simultaneously observe normal and abnormal tissue images at different microscopic powers. Students can interact with the images in a variety of ways, including rolling their mouse over areas of interest to obtain a description or following hyperlinks in the text. Divided into units relative to each system, each unit is accompanied by on online case-based problems. In addition, there are mini-

quizzes that provide immediate feedback about learning after each disease, and examinations

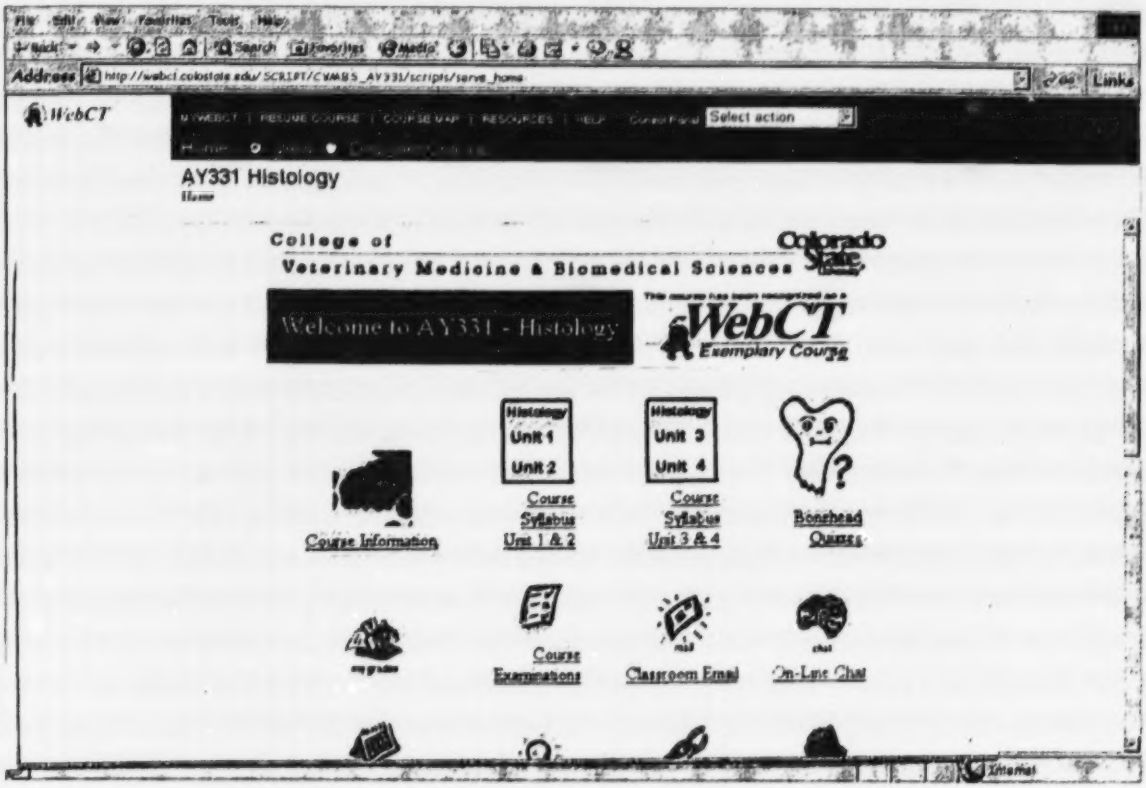

Figure 1: Screen capture showing organization of the Histology course.

after each unit. These modules are being tested in a variety of instructional situations during the 2001 – 2002 school year, with audiences ranging from undergraduate students to fourth-year professional students and faculty. Both qualitative and quantitative data are being gathered in order to assess their effectiveness, efficiency and appeal. The academic outcomes of this instruction are being investigated by a historical comparison study in which the final exam performance of veterinary students utilizing the modules in a Pathology course is compared to that of prior classes not utilizing the modules on the same exam. A cross-sectional study is also being carried out, in order to determine if prior knowledge affects users' perceptions of the materials.

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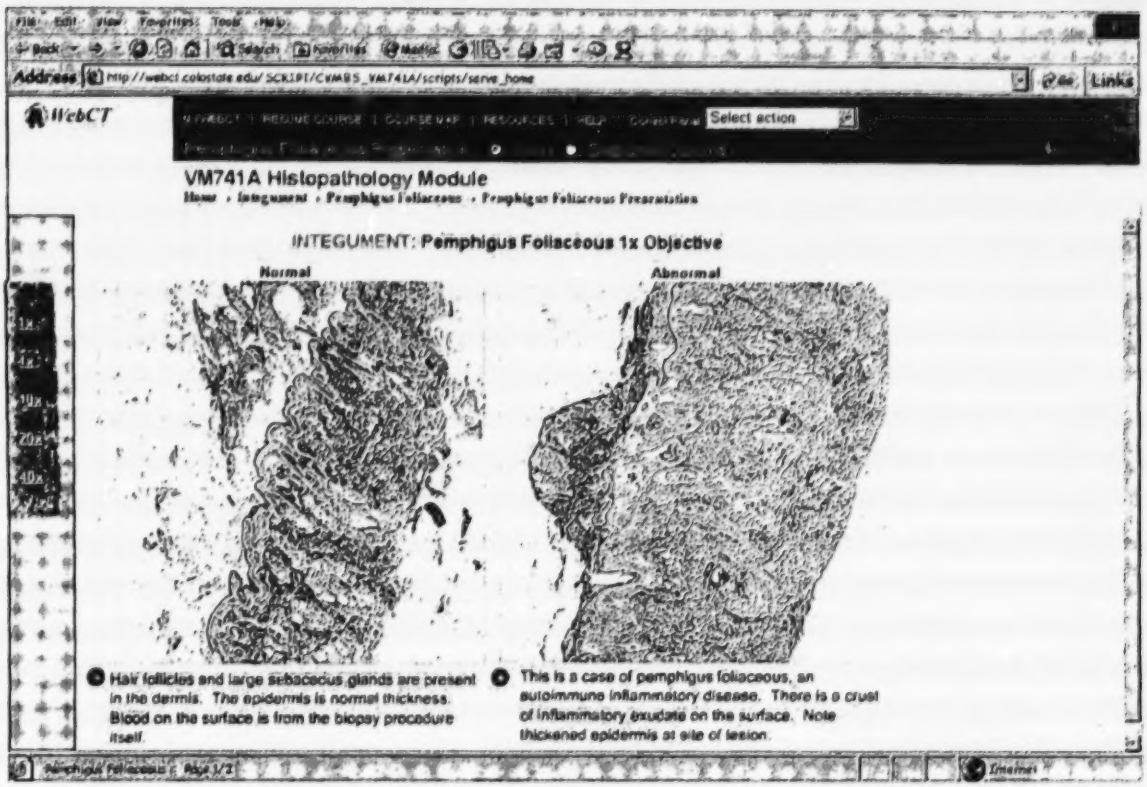
WebCT
Select action
VM741A Histopathology Module
INTEGUMENT: Pemphigus Follaceous 1x Objective
Normal
Abnormal
Hair follicles and large sebaceous glands are present in the dermis. The epidermis is normal thickness. Blood on the surface is from the biopsy procedure itself.
This is a case of pemphigus foliaceous, an autoimmune inflammatory disease. There is a crust of inflammatory exudate on the surface. Note thickened epidermis at site of lesion.

Figure 2: Sample screen from Histopathology course.

c) Physiology:

Online laboratories are currently being developed for these courses. The Physiology laboratories will focus on simulations, where students will be able to manipulate physiologic variables. For example, students will be able to raise or lower insulin in a virtual animal and observe its effect on plasma concentrations of glucose and fatty acids. This type of instruction will allow students to "learn by doing," and investigate cause and effect relationships, leading them to deduce the concepts underlying common physiological processes. A Java-based "Molecular Toolkit" and "Biomedical Hypertextbook" have already been developed in this area. The molecular toolkit allows students to carry out procedures such as restriction mapping in a virtual laboratory, and receive a report of their results much like they would obtain from the actual instrument. The hypertextbook takes advantage of hyperlinks to provide extensive contextual applications and examples for topics such as medical genetics. The goal is to convert these supplemental materials into a fully on-line course.

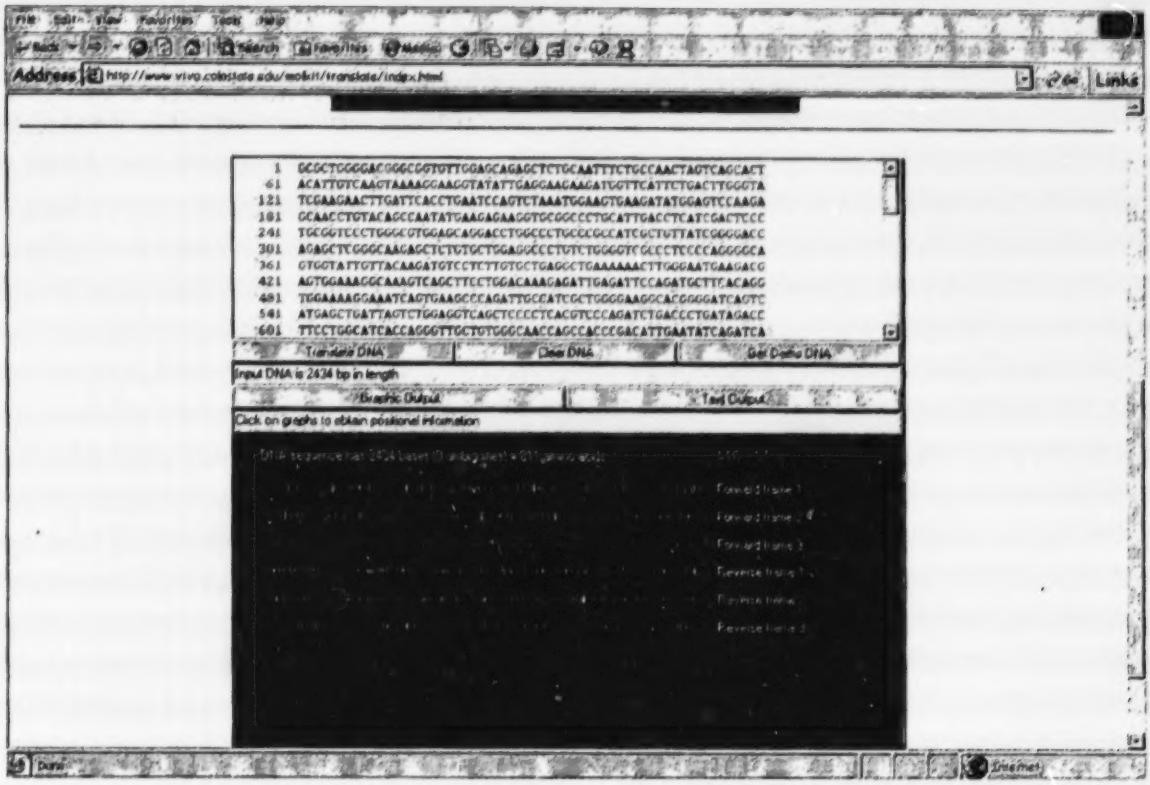

Figure 3: Screen capture from "Molecular Toolkit" in Physiology, showing the effects of various mutations on protein structure.

d) Microbiology:

In Microbiology, the online laboratories will emphasize specimen collection and handling procedures, and present interactive algorithms for isolation and identification of microorganisms that require students to select media, reagents, and tests, and then interpret results of each test. While these Authorware and Java-based materials are being developed, a preliminary version of the content is being tested in an undergraduate microbiology course. The supplemental materials are presented in WebCT and consist mainly of images showing positive and negative results of laboratory tests, as well as flow-chart schemes for their use. These materials scaffold the development of higher-order thinking skills by shifting the focus of instruction from how to conduct a specific laboratory test to interpreting the results of that test.

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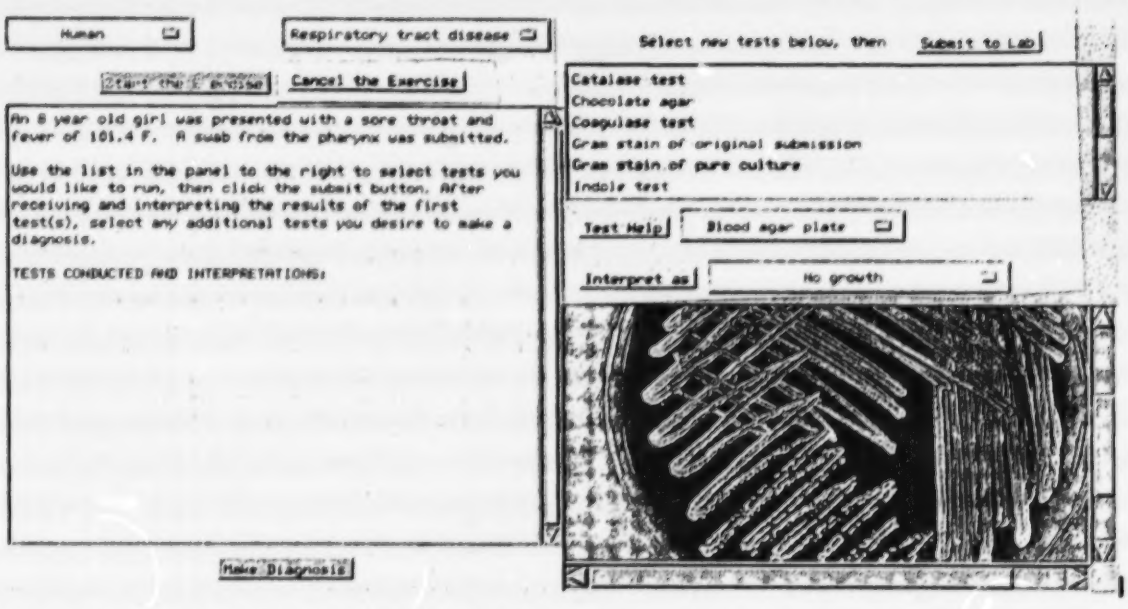
Human
Respiratory tract disease
Start the Exercise
Cancel the Exercise
An 8 year old girl was presented with a sore throat and fever of 101.4 F. A swab from the pharynx was submitted.
Use the list in the panel to the right to select tests you would like to run, then click the submit button. After receiving and interpreting the results of the first test(s), select any additional tests you desire to make a diagnosis.
TESTS CONDUCTED AND INTERPRETATIONS:
Make Diagnosis
Select new tests below, then
Submit to Lab
Catalase test
Chocolate agar
Coagulase test
Gram stain of original submission
Gram stain of pure culture
Indole test
Test Help
Blood agar plate
Interpret as
No growth

Figure 4: Sample fully interactive Microbiology laboratory exercise.

e) Farm Animal Anatomy:

An undergraduate course in domestic animal anatomy is currently being developed with funds from a U.S. Department of Agriculture grant. The purpose of this course is to meet the needs of animal science and pre-veterinary students (particularly those living in rural areas) who may have difficulty accessing this type of course in a traditional environment. Farm Animal Anatomy seeks to create a foundational understanding of the form and function relationships among anatomical structures across various species. When fully developed, this course will include on-line lectures (web-based), as well as clinical cases where students will apply their knowledge of anatomy to diagnosing an animal. An interactive, virtual reality laboratory component is also being developed. In this virtual laboratory, students will be able to interact with simulated cadavers, and manipulate images of structures (i.e. a skull) in a 3-D, virtual reality setting. These materials are currently being tested as a WebCT delivered supplement to the on-campus course, with the goal of offering the entire course at a distance during the 2003-04 school year.

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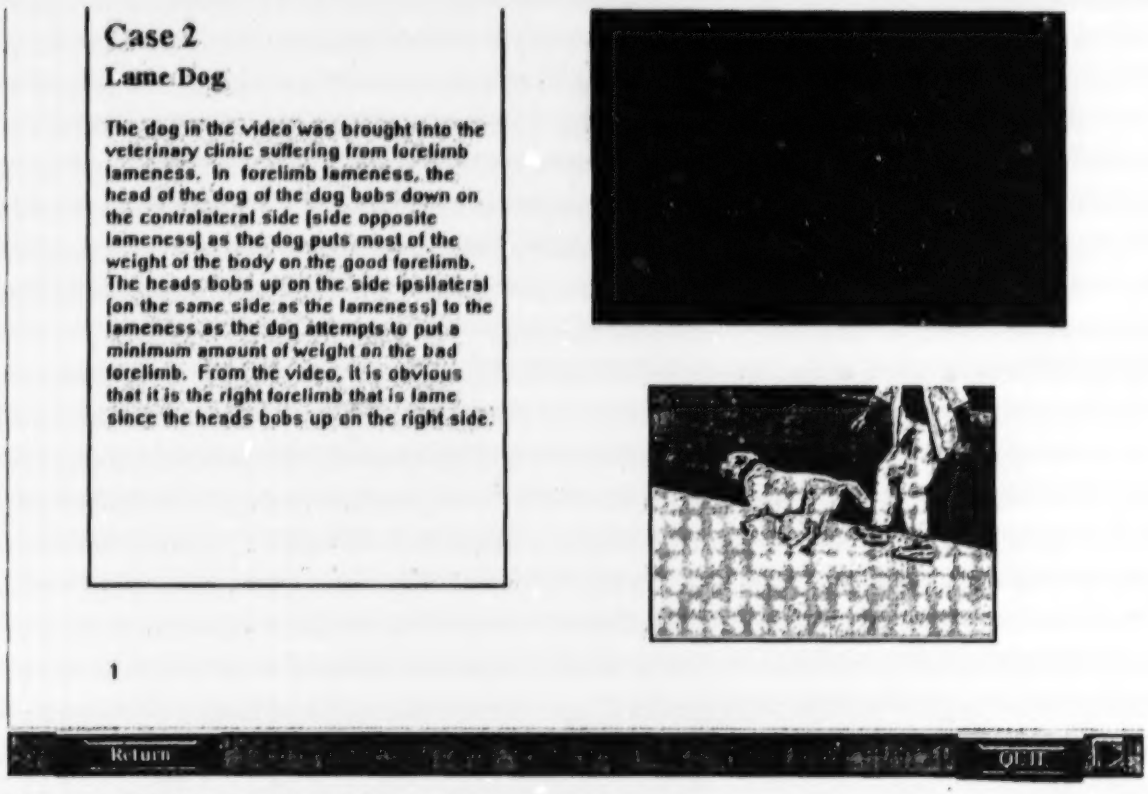
Case 2
Lame Dog
The dog in the video was brought into the veterinary clinic suffering from forelimb lameness. In forelimb lameness, the head of the dog of the dog bobs down on the contralateral side [side opposite lameness] as the dog puts most of the weight of the body on the good forelimb. The heads bobs up on the side ipsilateral [on the same side as the lameness] to the lameness as the dog attempts to put a minimum amount of weight on the bad forelimb. From the video, it is obvious that it is the right forelimb that is lame since the heads bobs up on the right side.
1
Return
QUIT

Figure 5: Clinical case from Farm Animal Anatomy.

Data Sources:

All online materials have been or will be tested by students enrolled in the appropriate courses for academic credit at a large, four-year university.

For the Histology course, study participants were students enrolled in an upper-level undergraduate Histology course. Eleven of the student participants were enrolled in the on-line section and 33 in the f2f section. Data were collected from a combination of chat transcripts, course exams and direct observations (lecture).

A much larger scale study is in progress for the Histopathology modules. It is estimated that a total of 685 participants will complete electronic surveys regarding their perceptions of the materials. Of these 685 people, approximately 100 will be undergraduates and 150 will be first year veterinary students, all utilizing the materials for enrichment purposes in other courses. Second-year veterinary students (135) are utilizing the materials as part of course requirements for "Biology of Disease Agents" and will provide the data for evaluation of academic outcomes.

Finally, 270 third- and fourth-year veterinary students and their instructors will assess the value of the modules in clinical situations. To date, 51 second-year veterinary students, 4 fourth-year veterinary students and 2 faculty members have tested and evaluated the modules.

The Farm Animal Anatomy materials are currently being beta-tested by the 150 undergraduate students enrolled in the campus course. As the Physiology and Microbiology laboratories are developed, they will be beta-tested by small numbers of students and faculty associated with the appropriate courses.

Results:

Drs. Schoenfeld-Tacher and McConnell (Schoenfeld-Tacher, McConnell & Graham, 2001) found that students in an online Histology course significantly out-performed their on-campus peers when given identical examination questions for the same material. In fact, although both groups were statistically indistinguishable from each other in performance on a content pre-test, by the end of the semester, the students enrolled in the on-line course significantly outperformed those in the on-campus course on a content post-test. These improvements were most likely associated with the observation that more instructional time was devoted to higher levels of thought (as measured by Bloom's Taxonomy) during the online sessions than during the on-campus sessions. Students initiated a larger percentage of interactions during on-line class sessions than in f2f sessions. When the topic of interactions was examined, the largest percentage of social interactions took place during on-line review sessions, while the greatest amount of content interactions occurred during f2f sessions. Further examination of content interactions showed that students in the lecture section generated significantly larger percentages of interactions at both the lowest levels of Bloom's Taxonomy than students in the other environments did. The only instance in which students initiated an appreciable percentage of high level (synthesis and evaluation) questions was the on-line class.

Data is currently being collected on the Histopathology materials. Results to-date indicate that each of the user groups (i.e. second- vs. fourth-year veterinary students) utilized the materials in a different manner and held different views about the major strengths of these modules. The more advanced students (N = 4), who tested the Integument module as part of a clinical rotation in Dermatology, reported more difficulties with navigation. These students expressed a distinct preference for and appreciation of the PBL cases and clinical applications.

They voiced a desire for the development of materials corresponding to microscopic topics (i.e. Biology of Disease, Histology) and expanded content sections. The sophomore veterinary students (N= 51) used the Integument and Respiratory modules as a supplement to a didactic Biology of Disease course. These students expressed an appreciation for the repetition and review of class material provided by the modules. They felt that the ability to simultaneously observe and compare normal and abnormal structures was the main advantage to using the materials. This group of students also appreciated the written descriptions of images and the correlation of normal vs. abnormal findings. They requested similar modules for other topics in the course. Overall, the more advanced students focused on applying the information to real-life situations, while the second-year students were more focused on memorization of facts and being able to identify microscopic structures.

Conclusions:

It is possible to teach science at a distance without sacrificing content rigor or the development of higher-order thinking skills. The key element is to approach the design of this type of instruction from a media AND methods standpoint, as opposed to a media VS. methods comparison or design problem. Faculty and course designers must first consciously separate content knowledge and scientific thinking/reasoning skills from psychomotor skills, and acknowledge the fact that our current technology does not allow for the teaching of psychomotor skills online. Once that distinction has been made, the next step is to clearly conceptualize the desired course outcomes, in the form of declarative knowledge, thinking skills and problem-solving skills. After this distinction has been established, an appropriate mix of teaching methods (i.e. problem-based cases, interactive simulations, etc) and media (Flash animation, video clips, html pages) can be selected to achieve the desired outcomes.

Based on the findings of the Histology study, it can be concluded that on-line delivery was an effective means of facilitating learner-content interaction (Moore & Kearsley, 1996) and creating learning opportunities equivalent to those available in the f2f course. Results of the Histopathology study demonstrated how the same set of materials could be designed for use by students with differing levels of prior knowledge and interests.

Educational Importance of the Study:

This study demonstrates that it is possible to teach a science course (including laboratories) entirely on-line without any adverse effects on academic outcomes. By addressing the effects of a delivery system on classroom interactions and academic performance for science content, this study makes a significant contribution to the body of knowledge about distance education. It questions the applicability of the many "no significant difference" findings for the comparison of two delivery media (Russell, 1999) in the case of science instruction. By further examining the feasibility of using the Internet to deliver laboratory instruction in the sciences, such as in the Physiology, Histopathology and Microbiology courses, this study explores the specific area of online science instruction and how it differs from instruction in other content areas. We will begin to establish guiding principles for online delivery of science instruction and lay the groundwork for further studies on the viability of offering entire college degrees in scientific areas completely at a distance.

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